Designing phosphors for brighter LEDs

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Light-emitting diodes or LEDs are steadily consolidating their share in the lighting and display market. This does however not mean that current technology is fully established yet. Contrary, improvements are still desirable, both for lighting and display applications.

White LEDs are typically built from a blue emitting $In_{1-x}Ga_xN$ pumping LED and one or multiple phosphors which convert the blue light into green, yellow and red light in order to complete the visible spectrum and to obtain the desired white light.

Depending on the application of the LED, the specifications for the white light are completely different. For lighting, a compromise between a high color quality and a good luminous efficacy has to be made, while for display applications, saturated primary colors are indispensable.

Currently, only a handful of phosphor materials exist that can meet the strict requirements needed for applications. Furthermore, so called rare earth elements (such as Ce, Eu, Y, Lu) form an important building block of these phosphors, making their synthesis expensive and environmentally unfriendly and the availability of phosphors susceptible to market shortages.

Because of the increasing demand and the difficulties with current materials, it is desirable to develop novel phosphor materials with improved properties. To obtain this goal in an efficient way, a combination of experimental research and modelling of the electronic and optical properties of the phosphor materials is used.

Careful analysis of the experimental input of photoluminescence emission and excitation spectra, luminescence decay measurements and thermal quenching of the fluorescence allows to distill empirical energy level schemes of the optically active region of the luminescent material. These energy level schemes offer a deeper understanding about the interactions on the atomic scale which drive the luminescence process. If the reasoning is inverted, luminescent properties can be predicted in advance and suitable dopant-host combinations selected without the need of numerous syntheses.

In addition, structure analytical techniques, such as the powerful combination of cathodoluminescence spectroscopy and scanning electron microscopy are utilized to gain knowledge about the crystallography and synthesis process of the phosphor powders that came out of the empirical selection procedure.